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Cone and Seed Yields from Controlled Breeding of Southern Pines

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Cone and Seed Yields from Controlled Breeding of Southern Pines

E. B. Snyder [1] and A. E. Squillace [2]

Low seed yield from controlled pollination is seriously hampering tree breeding in the South. To define the problem in quantitative terms, data were assembled from routine pollinations made during the past 10 years by the U. S. Forest Service in Florida, Georgia, Louisiana, Mississippi, and Arkansas.[3]

Generally, isolation bags of synthetic sausage casing, and carburetor-type, cloud-producing applicators were used *(5)*. The reason for prevailingly low yields is unknown, and disappointments will continue unless research discovers the biological or procedural causes.

INTRASPECIES POLLINATIONS

Records from controlled pollinations of slash pine *(Pinus elliottii* Engelm.) in the vicinity of Olustee, Fla., and Gulfport, Miss. (hereafter referred to as field stations), were most extensive and are set forth in table 1. Average cone and seed yields for all trees for each station-year show that stations realize approximately the same yields overall, but that for cross pol-

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[3] Data were contributed by J. C. Barber, H. J. Derr, H. C. Grigsby, F. F. Jewell, D. M. Schmitt, R. J. Varnell, and P. C. Wakeley, in addition to the authors.

Table 1.—*Yields from intraspecific pollinations of slash pine at Olustee, Fla., and Gulfport, Miss.*

Pollination year	Olustee, Fla.— Baker, Clay, Columbia, Union Counties					Gulfport, Miss.— Harrison County				
	Seed parents	Flowers pollinated	Cone survival [1]	Seeds per flower [2]	Seeds per cone [2]	Seed parents	Flowers pollinated	Cone survival [1]	Seeds per flower [2]	Seeds per cone [2]
	– Number –		*Percent*	*– Number –*		*– Number –*		*Percent*	*– Number –*	
				CROSS-POLLINATED [3]						
1956	12	385	73	22.1	30.3	7	206	61	30.7	51.4
1958	5	184	41	5.2	12.6	4	70	33	1.6	5.0
1959	3	273	52	2.4	4.6	6	285	33	11.6	35.0
1960	61	1,024	54	19.1	35.4	5	60	47	9.0	19.2
1961	11	168	30	1.7	5.5	8	411	22	3.5	15.6
1962	19	283	24	5.1	19.1	9	373	42	12.5	29.8
				SELF-POLLINATED						
1956	2	3	100	7.3	7.3	9	66	44	6.5	14.8
1957	1	5	20	2.8	14.0	5	46	67	1.5	2.2
1958	4	61	46	4.5	9.8	4	21	19	.8	4.2
1959	4	167	40	1.3	3.4	3	50	46	10.6	23.1
1960	3	27	85	5.0	5.8	4	35	43	.6	1.3

[1] (Cones harvested/flowers pollinated) × 100.

[2] In this and other tables, sound seed averages are weighted by the number of flowers or cones per tree.

[3] One or more pollens per seed tree were used.

linations in a given year the agreement between stations is only fair.

Table 2 combines data for slash, longleaf (*P. palustris* Mill.), loblolly (*P. taeda* L.), and shortleaf (*P. echinata* Mill.) pine at Olustee, Gulfport, and other field stations. Over 23 station-years, only 40 percent of cross-pollinated slash pine flowers lived to maturity. This low survival depressed the yield per pollinated flower to a mean of 11 sound seeds. The mode was 5 seeds! Mean yield from cones collected was 28 seeds, with a mode of 19. Under self-pollination, one-eighth to one-sixth as much seed was harvested per flower or cone as for cross pollination—1.4 seeds per flower and 4.4 seeds per cone. Wind pollinations produced 46 seeds per cone.

Loblolly and shortleaf pines had the same tendencies as slash pine. Longleaf also follows the trend in 12 of the 14 station-years. The other two station-years were 1961 and 1962 at Alexandria, in Rapides Parish, Louisiana. Here average yields per year for the controlled crosses were as high as 82 seeds per cone, as

Table 2.—*Means and ranges for cone survivals and seed yields from various types of pollination, 1954-1962*

Type of pollination	Station-years	Seed parents [1]	Flowers	Cones	Cone survival		Seeds per flower		Seeds per cone	
					Mean	Range [2]	Mean	Range [2]	Mean	Range [2]
	Number				*Percent*		*Number*			
SLASH (MAINLY FLA. AND MISS.) [3]										
Cross (all station-years)	23	193	4,626	1,838	40	0-73	11.2	0-39	28.3	0-56
Wind	6	142	...	1,165	...	...	...	...	46.1	27-73
Comparable cross	6	53	1,689	632	37	22-69	9.2	2-39	24.6	4-56
Self	16	89	3,288	1,015	31	19-100	1.4	1-11	4.4	1-23
Comparable cross	16	154	3,903	1,566	40	10-73	10.9	1-31	27.3	1-51
LONGLEAF (MAINLY LA. AND MISS.) [3]										
Cross (excluding La. 1961 and 62)	12	64	2,524	930	37	15-75	10.5	1-22	28.6	1-72
Cross (all station-years)	14	97	4,061	1,502	37	15-75	17.3	1-37	46.9	1-82
Wind } (excluding La.	2	22	...	658	...	...	...	...	58.3	35-59
Comparable cross } 1961 and 62)	2	10	360	78	22	17-24	5.6	5-6	25.7	23-33
Wind } (all station-	4	43	...	938	...	...	...	...	56.7	33-62
Comparable cross } years)	4	43	1,897	650	34	17-54	24.2	6-37	70.6	23-82
Self	5	41	259	89	36	5-46	7.1	1-8	19.6	1-60
Comparable cross	5	47	2,416	905	37	17-75	19.9	6-25	53.0	14-82
LOBLOLLY (MAINLY ARK. AND MISS.) [3]										
Cross (all station-years)	11	110	7,888	2,601	33	15-58	6.1	1-17	18.5	2-42
Wind	2	34	...	170	...	...	...	...	20.1	17-24
Comparable cross	2	34	2,864	1,155	40	37-50	4.8	4-8	11.8	10-15
Self	7	36	468	193	41	0-53	.9	0-3	2.1	0-20
Comparable cross	7	72	5,113	1,695	33	15-50	3.5	1-8	10.5	2-14
SHORTLEAF (MAINLY ARK. AND GA.) [3]										
Cross (all station-years)	5	25	944	564	60	0-90	11.1	0-17	18.6	0-28
Wind	2	2	...	10	...	...	...	...	10.7	...
Comparable cross	2	2	32	13	41	...	.5	...	1.5	...
Self	1	2	43	17	39	...	.0	...	.0	...
Comparable cross	1	4	210	88	42	...	1.9	...	4.6	...

[1] Sum of trees per year pollinated by one or more pollens. In many cases, some of the same trees were used from year to year.

[2] Range is among station-years.

[3] Fla.—Includes Baker, Clay, and Union Counties, Fla., and Jeff Davis, Atkinson, Tift, and Berrien Counties, Ga.
Miss.: Harrison and Greene Counties.
La.: Rapides and Sabine Parishes.
Ark.: Ashley County, Ark., Morehouse Parish, La.
Ga.: Jones, Bleckley, and Clarke Counties.

compared to 62 for the wind—one of the few instances where controlled pollinations exceeded wind pollinations.

The wind-pollination results can be compared to the ranges for seed yields per cone found by Wakeley *(8)*: slash 60-70, longleaf 50-60, loblolly 40-50, and shortleaf 25-35, with half these yields realized in poor seed years. Poor years occurred about half the time between 1954 and 1962, according to the data from which summary tables were made.

INTERSPECIES POLLINATIONS

Species hybrids, particularly *longleaf* × *slash* and *shortleaf* × *slash,* have commercial potentialities in the South. Seed yields from such crosses are summarized in table 3. The small amount of data precludes subdividing the table as was done in table 2.

Average yields from interspecific crosses were, with one exception, inferior to those from intraspecies crosses. However, the dif-

Table 3.—*Mean cone survival and seed yields from interspecific controlled pollinations, 1953-62*

Male parent	Station-years [1]	Seed parents	Flowers	Cone survival	Seeds: Per flower	Seeds: Per cone
	Number	*Number*	*Number*	*Percent*	*Number*	*Number*
SLASH PINE FEMALE						
Longleaf	8	28	356	24	0.3	1.4
Loblolly	7	39	732	37	4.1	11.2
Shortleaf	6	59	3,847	42	1.8	4.3
Sonderegger	5	12	249	26	.4	1.6
Slash (controlled)	11	46	1,544	38	10.8	28.4
LONGLEAF PINE FEMALE [2]						
Slash	19	83	1,733	32	11.8	37.3
Loblolly	12	41	990	4	.6	14.4
Shortleaf	4	7	88	0	.0	.0
Sonderegger	5	13	220	26	10.0	38.1
Longleaf (controlled)	14	96	4,061	37	17.3	46.9
LOBLOLLY PINE FEMALE						
Slash	13	47	1,689	20	.5	2.6
Longleaf	10	42	1,461	16	.3	1.8
Shortleaf	3	8	345	9	.2	1.8
Sonderegger	4	20	601	50	7.8	15.6
Loblolly (controlled)	10	105	7,193	36	6.6	18.2
SHORTLEAF PINE FEMALE [3]						
Slash	14	94	8,075	34	2.9	8.5
Longleaf	5	8	476	25	.1	.2
Loblolly	10	32	1,874	36	5.6	15.8
Sonderegger	2	5	98	28	.1	.2
Shortleaf (controlled)	4	23	912	60	11.5	19.1
SONDEREGGER PINE FEMALE						
Slash	4	9	182	46	13.9	30.2
Longleaf	6	15	375	51	12.0	23.4
Loblolly	6	17	443	57	19.4	34.0
Shortleaf	3	4	40	30	5.2	17.3
Sonderegger (controlled)	5	16	309	63	23.8	37.5
Wind	1	4	...	[4] 20	...	25.6
Self	4	13	305	60	3.1	5.1

[1] 1955 results excluded since late spring freeze caused nearly total failure throughout the South.

[2] The data are mostly from Ashley County, Ark., Morehouse Parish, La., and Harrison County, Miss. Some crosses with longleaf include results from Rapides and Sabine Parishes, La.

[3] Some crosses with shortleaf are from Clarke County, Ga. Most of the shortleaf × slash crosses were in Sabine Parish, La.

[4] Number of cones.

ferentials are sometimes small: e. g., *longleaf × slash* vs. *longleaf × longleaf* yielded 12 vs. 17 seeds per flower and 37 vs. 47 seeds per cone. In several individual instances, furthermore, the interspecies crosses were as good as the intraspecies. It should be noted that crosses of Sonderegger pine, *Pinus × sondereggeri* H. H. Chapm., represent backcrosses or multiple-species crosses rather than F_1 crosses.

The following tabulation compares values in table 3 with results from some of the same crosses at Placerville, California *(3)*; the data are seeds per cone:

	Placerville	*Southern U. S.*
Loblolly × longleaf	<0.1	1.8
Loblolly × slash	3.0	2.6
Shortleaf × longleaf	.6	.2
Shortleaf × loblolly	16.5	15.8
Shortleaf × slash	24.0	8.5
Slash × longleaf	26.9	1.4

In the first four comparisons agreement is excellent. Reasons for discrepancies in the last two are not known. For the shortleaf × slash cross there were only five attempts at Placerville—perhaps too few to average out variation among individual trees. The low value in the South for the slash × longleaf cross and other hybrids with slash is attributed to deterioration of pollen stored nearly a year.

RESULTS WITH STORED POLLEN

Breeders often assume that because their stored pollen germinates well it will set as much seed as fresh pollen. The data in table 4 indicate that stored pollen is apt to produce poor seed yields. Campbell and Wakeley *(2)* reached similar conclusions. Review of storage methodology seems called for, because many of the poor seed yields reported here were with pollen stored according to specifications *(6)* and having germinability up to 95 percent.

Table 4.—*Cone survival and seed yields after the use of stored and fresh pollens* [1]

Cross and pollen condition	Seed parents	Flowers	Cone survival	Seeds per flower	Seeds per cone
	– Number –		*Percent*	*– – Number – –*	
Slash × loblolly					
Stored	3	34	24	0.3	1.5
Fresh [2]	1	23	87	17.7	20.4
Longleaf × sonderegger					
Stored	1	10	10	1.8	18.0
Fresh	1	9	78	104.2	134.0
Longleaf × slash					
Stored	3	172	47	2.5	5.4
Fresh	5	108	44	3.6	8.2
Slash × slash					
Stored	2	12	33	4.6	13.7
Fresh	5	184	41	5.2	12.6
Slash × slash					
Stored	4	64	44	.6	1.3
Fresh	4	70	33	1.6	5.0
Slash × slash					
Stored	7	385	29	.1	.2
Fresh	5	60	47	9.0	19.2
Slash × slash					
Stored	6	170	31	.9	3.0
Fresh	8	411	22	3.5	15.6
Slash × slash					
Stored	4	64	36	3.4	9.6
Fresh	9	373	42	12.5	29.8

[1] Fresh pollen is defined as having been collected no more than 1 month before use; stored pollen was collected from 11 to 13 months before use. Each comparison is from one of three stations and in 1 of the 7 years such tests were conducted.

[2] Pollen was obtained from loblolly strobili stimulated by pollen sawflies.

YEAR OF CONE LOSSES

After cross-pollination, 70 to 90 percent of total cone loss occurred within the first year (table 5). After selfing, percentages lost the first year were relatively less than those for crossing in all species except loblolly. In a breeding program, such knowledge in conjunction with 1-year cone counts allows prediction of seed yields and indicates if additional pollinations for any estimated low-yielding combinations are advisable.

Table 5.—*First-year cone loss at Institute of Forest Genetics, Gulfport, Miss., 1955-1962*

Species and type of pollination [1]	Flowers pollinated	Total cones lost	First-year loss as proportion of total loss
	– – Number	*– –*	*Percent*
Slash			
Cross	2,549	1,602	78
Self	296	149	60
Longleaf			
Cross	2,317	1,597	89
Self	254	164	77
Sonderegger			
Cross	1,234	568	84
Self	68	26	54
Loblolly			
Cross	5,148	3,366	70
Self	187	103	86
Shortleaf			
Cross	3,054	2,056	90

[1] Crosses are intra- and interspecific.

DISCUSSION

Two questions are of special interest: How reliable are our data, and how can the yields be improved?

It can be argued that our averages are biased. Contributors reported that some flowers that should have been counted were omitted, and that not all empty seeds were excluded. Either error would inflate our yields per flower. Then there are the fluctuations in weather. During 1955 most cones froze. Some 1955 results were excluded on the basis that such an occurrence might be rare. Moreover, "good" years predominate in the data; i. e., averages are weighted by the number of flowers pollinated per year. Foresters allege that when cones are numerous seed yields per cone are also high. Since numbers of controlled pollinations increase during such years, our figures exceed unweighted averages.

On the other hand, underestimation results where stored pollen was used but not reported. It appears that our experimental values from wild trees do underestimate the situation for clonal seed orchards in Georgia (table 6). They are also less than results from wind pollination in loblolly seed-production areas of Georgia: viz. the 20 seeds per cone noted in table 2 and the 89 reported by VanHaverbeke and Barber *(7)*. These two authors culled 12 percent of cones for damage. We collected all cones in order to get maximum seed but found that yields per cone would have been increased 40 percent if damaged cones had been discarded. Whether the Georgia discrepancies are due to a geographic effect, better cultural conditions, more cone culling, or better pollinations is impossible to say until data from other orchards and production areas are available.

Since the relative strength of factors for overestimation and underestimation are unknown, we assume that our yield estimates are realistic.

Controlled pollinations generally yielded less seed per cone than wind pollinations. Failures in pollination and fertilization undoubtedly account for part of the difference. Reevaluations should be made of the pollen-handling procedures *(6)*, the flower stages at which pollen is applied *(2)*, and the type of pollination bag *(4)*. Improved storage and an accurate laboratory method of measuring the fertilizing ability of pollen should help. Investigations are needed on normal pollination and fertilization processes as well as those occurring after application of too much or too little pollen, dead pollen, or pollen diluents *(1,2,9)*.

Part of the difference between seed yields from controlled and wind pollinations may be due to genetic incompatibilities between parents. In most controlled crosses, the pollen is from a single male. However, when we simulated wind-pollination by using multi-pollen mixes, an average of 29 seeds per cone was obtained as compared to 18 when the same pollens were applied singly.

Information on mortality of wind-pollinated cones is limited, but we have recent preliminary data indicating that there is not much difference in cone mortality between types of pollination. To the benefit of both types, trees

Table 6.—*Cone and seed yields from controlled pollinations—clonal seed orchards in Ga.*

Pollination year	County	Clones	Flowers	Cone survival	Seeds	
					Per flower	Per cone
		– – Number – –		*Percent*	*– – Number – –*	
		SLASH PINE				
1958	Wheeler	30	342	77	39.8	51.8
1958	Pulaski	62	. . .	[1] 576	. . .	52.2
1959	Wheeler and Pulaski	32	220	94	30.1	32.0
1960	Wheeler and Pulaski	87	3,217	83	41.5	49.8
1961	Wheeler and Pulaski	101	[2] 4,206	[2] 85	[2] 37.4	44.1
1962	Wheeler and Pulaski	36	[2] 605	[2] 86	[2] 38.9	45.2
		LOBLOLLY PINE				
1958	Bleckley, Wheeler, and Pulaski	45	. . .	[1] 166	. . .	73.8
1959		15	105	81	28.0	34.6
1960		68	1,300	75	15.2	20.2
1961		75	[2] 2,285	[2] 73	[2] 25.7	35.1
1962		61	[2] 1,491	[2] 66	[2] 17.4	26.5

[1] Number of cones.

[2] Number of flowers believed to be underestimated, thus causing upward bias in cone percentage and number of seeds per flower.

can be selected for their good general cone- and seed-yielding ability. This observation is supported by results from a slash pine seed-production area in which yields from controlled pollinations were inferior to but correlated with yields from wind pollinations. Only 25 percent of the trees gave satisfactory yields even from wind-pollinated cones.

Since cone losses are believed due in large measure to insects, insect identification and control may be critical for both wind- and controlled-pollinations. Likewise, a knowledge of other factors such as weather and site conditions influencing cone and seed yields will be important to seed orchard managers as well as tree breeders.

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